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BLACK LOCUST, PINES, AND SASSAFRAS
AS BUILDERS OF FOREST SOIL

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Soil conditions on areas selected for reforestation in the Central States are often very unfavorable. Litter-protected, porous surface soil has been broken by cultivation and removed by erosion. The compact soils thus exposed are incapable of absorbing rainfall adequate for satisfactory tree growth; also, being uninsulated and low in moisture, they have critical high temperature extremes.

The suitability of a tree species as a pioneer for reforestation under such soil conditions depends definitely on three properties: Ample leaf production, persistence of litter cover on the soil surface, and a type of litter decomposition that favors organic-matter incorporation into the mineral soil. Accumulation of a litter cover on the bare mineral soil is necessary for development of desirable forest soil porosity. Organic matter in mineral soil (in addition to constituting a reserve supply of plant nutrients) aids in effecting flocculation and formation of soil aggregates. Litter cover preserves porosity from destruction by impact of rain, and prevents clogging of the porous mass by muddy water; only filtered water enters a litter-protected forest soil. Increased soil porosity influences infiltration rate, which to a great extent determines the quantity of water stored in the soil. Without adequate soil water the productive forest is impossible.

Certain pines -- particularly shortleaf, Virginia, and pitch -- have been used extensively and successfully for planting on dry sites in the Central States. Black locust has been planted for erosion control because, although it may not develop satisfactorily later, it does persist in the early stages on some very poor sites. Sassafras has not been planted, but regenerates easily and extensively. It is considered a pest in many farming sections, because it invades cultivated fields and often spreads under tillage with great rapidity. The present investigation was designed to determine how black locust, certain pines, and sassafras compare in soil-building properties as measured by weight of litter per acre, quantity of organic matter incorporated in the mineral soil, and rate of water infiltration into the soil. The pines included in the study were shortleaf, Scots, Austrian, eastern white, and red. Nitrogen in the upper soil of locust and sassafras areas previously used for agriculture was compared with that in corresponding old-field soils, because nitrogen content of a soil is derived largely through organic-matter incorporation and affords a valuable measure of soil improvement. Calcium and nitrogen contents of the litters of black locust, pines, and sassafras also were determined, because of their influence on rates of decomposition and incorporation into the soil. In addition, a complete inventory of organic matter was made on a black locust and a nearby sassafras stand on old-field areas.

Study Areas and Sampling

The investigation was made on three areas: The Shawnee Experimental Forest, Hardin County, Ill.; the Morgan-Monroe State Forest, Ind.; and the Brown County State Park, Ind.. These areas were considered representative of the rough abandoned land in much of the unglaciated portion of the Central States. The predominating soil type of all three areas is Muskingum silt loam. Use was made of 56 wooded plots, each 20 feet square: 18 black locust, 11 pine, and 27 sassafras. These plots were selected on the basis of complete stocking and of uniformity as to litter cover and microrelief. The stands were even-aged, and represented as wide a range of ages as could be found within the study areas. With each wooded plot an adjacent nonforested old-field plot was matched.

When each 20- by 20-foot plot had been located, stakes were driven at the corners and a string stretched around them. Two numbers were drawn at random from the series 1 to 20. The first number of feet was measured from the south-east corner along the eastern border, and the second number of feet was measured from the northeast corner along the northern border. Perpendiculars were drawn from the north and east sides at the points thus located, and their point of intersection within the plot was made the southeast corner of a 1-foot-square sampling area. Another sampling area of the same size was similarly located by measurements along the west and south sides from the southwest and northwest corners, and the litter from each of the two areas was bagged. Four areas for an infiltration test were similarly located, and on these soil samples were taken from each of two horizons, the A_1 and the A_2 . The corresponding soil-horizon samples from each of the two areas were mixed. This gave two A_1 and two A_2 composite samples.

Litter and Its Influence

The two samples of litter taken from each plot were dried and weighed, and their weights were corrected for adhering soil. The average corrected weights, by species and age of stands, are presented in table 1.

Table 1.--Oven-dry weight of litter per acre

Age class of stand (years)	:	Black locust	:	Pines	:	Sassafras
	:		:		:	
		<u>Pounds</u>		<u>Pounds</u>		<u>Pounds</u>
0-5		5,400		-----		5,000
6-10		8,600		1/ 3,555		5,500
11-15		8,300		1/ 17,800		6,400
16-20		12,300		-----		7,400
21-25		10,200		2/ 20,600		6,800

1/ Value not strictly comparable with those for black locust and sassafras, because based on samples taken only directly under trees.

2/ Value comparable with those for black locust and sassafras, because the crown canopy was closed and the litter cover fairly uniformly distributed.

The relative weights of litter per acre of locust, pines, and sassafras in the 21- to 25-year age group approximated 10,000, 20,000, and 7,000 pounds, respectively. The data indicate that the pines have a superior usefulness in developing protective litter cover on bare land for erosion control and site improvement.

The leaf litters of black locust, pines, and sassafras differed widely in chemical composition (table 2). Calcium and nitrogen contents of black locust

Table 2.--Average calcium and nitrogen contents
of litter of black locust, pines, and
sassafras

Species	Calcium	Nitrogen
	Percent	Percent
Black locust	3.22 \pm 0.115	2.81 \pm 0.37
Pines	.46 to 2.40	.64 to 2.66
Sassafras	1.57 \pm 0.054	1.59 \pm 0.053

litter were almost double those of sassafras litter. Shortleaf pine litter averaged only 0.70 percent calcium and 1.07 percent nitrogen, whereas Scots pine averaged 1.66 percent calcium (minimum 1.11 percent, maximum 2.40 percent) and 2.20 percent nitrogen. The litter composition of Scots pine would seem to favor rapid decomposition more than that of other pines, but observations on Scots pine litter do not indicate that it differs much in that respect from the litter of other pines.

The influence of the litter of these species on soil profile formation is to some degree independent of chemical composition. The predominant factors in it are (1) physical characteristics that influence desiccation and (2) palatability. Because of its relatively high calcium and nitrogen content, the litter of black locust presumably would decompose and become incorporated in the mineral soil as rapidly as that of sassafras,^{1/} except that it dries out more quickly and does not make so intimate a contact with the mineral soil, and thus is not so readily eaten by soil fauna. Possibly, also, it is not so palatable as the other litters. Pine litter, likewise, lies loosely and because of its lightness dries out quickly.

Partly because of this looseness of the litter, and still more because of liberation of nitrogen from decomposed nodules and litter, luxuriant growth of grass and weeds is very common under black locust; under sassafras or pines, such growth is rare or nonexistent. If a young natural stand of black locust is very dense, with closed crown canopy, grass will be absent for a period of years; when the stand becomes less dense through natural thinning, however, grass will

^{1/} Gast, P. R. Contrast Between the Soil Profiles Developed under Pines and Hardwoods. Jour. Forestry 35: 11-16. 1937

Broadfoot, W. M., and Pierre, W. H. Forest Soil Studies: I. Relation of Rate of Decomposition of Tree Leaves to Their Acid-Base Balance and other Chemical Properties. Soil Sci. 48: 329-348. 1939.

occupy the forest floor. If pasturing is practiced at the latter stage, tree reproduction is inhibited and a grass sod is likely to form. Grass sod makes it difficult for trees of other species to develop under the locust.

Incorporated Organic Matter

Darkening of the soil by organic matter in most cases did not extend below 2 inches. By subtracting loss on ignition of the A₂ horizon (usually the 4- to 6-inch zone) from that of the A₁ horizon (the 0- to 2-inch zone), the superiority of the latter in organic matter was estimated. Igniting a soil not only removes volatile and combustible material but also drives off any chemically combined water held by the minerals; hence, to estimate organic-matter content of soil it is necessary to correct simple loss on ignition for loss of combined water. It was assumed that, because of cultivation, the soil of the A₁ and A₂ horizons had been fairly homogeneous as to combined water at the time when the study areas were abandoned for agriculture, and had remained so. Thus, when the ignition loss of an oven-dry A₂ soil sample was subtracted from that of an oven-dry A₁ sample, it was considered that the losses of combined water had been equal and that the remainder represented only volatile and combustible organic matter added to the A₁ soil horizon by organic debris since time of abandonment. This difference offers a means of comparing the soil-building properties of woods and field vegetation. The results of such comparison for black locust, pine, and sassafras plots are presented in table 3.

Table 3.--Difference between woods and adjacent old-field soil in organic matter added to A₁ horizon since land abandonment, in pounds per 500,000, 1/ for black locust, pines, and sassafras

Black locust	:	Pines	:	Sassafras
<u>Pounds</u>		<u>Pounds</u>		<u>Pounds</u>
+ 8,300		- 1,750		+ 450
- 3,400		- 2,500		+ 7,650
+ 3,750		- 8,000		+ 500
- 2,200		- 6,050		+ 2,400
+ 4,050		- 4,800		+ 800
- 3,450		- 2,200		+ 2,950
- 4,050		+ 8,900		+ 4,200
0		+ 7,750		+ 9,300
- 2,800		+ 1,700		+ 950
+ 4,450		+ 3,700		+ 4,200
- 3,450		- 700		+ 500
+ 1,450				+ 1,850
+ 3,000				+ 1,600
- 700				+ 7,400
- 1,350				+ 1,250
+ 4,050				+ 1,450
				+ 3,150
				+ 600
				+ 3,600

1/ This ratio was chosen because 500,000 pounds is the approximate weight of a 2-inch layer of soil covering an acre, as determined by sampling.

The significant point in this comparison is that all sassafras woods soils showed positive superiority in organic-matter accumulation over the corresponding field soils. In 8 out of 15 locust woods soils, organic-matter content was less than in the corresponding field soils. Similarly, out of 11 pine woods soils 7 had less organic matter than the corresponding field soils. Evidently sassafras had proved superior to locust and pine as a contributor of humus to the mineral soil.

Nitrogen in Mineral Soil

Accumulation of nitrogenous substances in the upper mineral soil is one of the indexes of fertility. Any differences in nitrogen content between the A₁ and A₂ soil horizons on the study areas was attributed to accumulation since abandonment, and superiority of any soil in nitrogen content may be attributed to character of vegetative cover. Nitrogen accretion was assumed to be confined to the A₁ soil horizon, because any nitrogen mobilized from organic matter would have been removed by leaching. Table 4 presents a series of values for black locust

Table 4.--Difference between woods and adjacent old-field soil
in nitrogen added to A₁ horizon since land abandon-
ment, in pounds per 500,000, for black locust and
sassafras

Black locust	:	Sassafras
<u>Pounds</u>		<u>Pounds</u>
+ 343		- 32
- 46		+ 330
+ 133		- 85
+ 41		+ 48
+ 259		+ 180
- 57		+ 44
- 91		+ 228
- 146		+ 325
- 189		
+ 413		
- 50		
- 26		
+ 172		
+ 64		
- 31		
+ 148		

and sassafras plots derived by subtracting the nitrogen weight of the A₁ horizon of a field plot from that of its paired woods plot. Such values were not calculated for pine plots because the pines are known not to be nitrogen fixers; furthermore, nitrogen-containing organic matter does not become incorporated in pine soil under normal conditions, and any nitrate nitrogen liberated from surface debris is soon lost by leaching.

The important point brought out by table 4 is the low nitrogen content of the black locust soil. It is well known that black locust litter is high in protein, but apparently its nitrogen does not get into the mineral soil in a form

amount permitting accumulation. Abundant nodules occur generally on black locust roots, and they are known to be high in nitrogen; but apparently sassafras, although not a legume, had caused as much nitrogen accumulation in the soil as locust. When actual volume of root nodules is compared with soil volume this does not seem strange, especially as the nodule protein is easily nitrified. That much nitrogen is fixed by black locust cannot be doubted, but probably it is quickly absorbed by plant roots or lost by leaching. This rapidly evolved nitrate nitrogen might well be utilized by trees of more valuable species planted with the locust.

Complete Organic Matter Inventory

The changes in litter from the time it accumulates until it becomes incorporated in the mineral soil are well illustrated by data collected in midsummer on two additional 20-by-20-foot plots in an old-field stand of black locust and a nearby old-field stand of sassafras. The stands were aged 9 and 12 years, respectively. All trees on the two plots were cut, and their leaves plucked. Litter was collected down to the mineral soil, and the A₁ and A₂ soil horizons were sampled. Oven-dry weight of organic matter was determined on leaves, litter, and soil, and in addition the live annuals were collected and weighed separately. The results are shown graphically in figure 1. Leaf weights were about equal, organic matter of live annuals and dead material was greater on the locust than on the sassafras area, and organic-matter incorporation was much greater in the sassafras soil. These data agree with those collected from the other sample plots in showing that more organic debris collects on an area covered with black locust than on one covered with sassafras, but that a great deal more organic matter enters the sassafras soil than enters the black locust soil.

Infiltration Rate

One of the most significant evidences of improvement in a denuded, impoverished soil is increase in the rate at which the soil absorbs rainfall. Infiltration rate is controlled by soil porosity; hence as the soil mellows its infiltration rate increases. In this study, infiltration rate was determined by means of a 1-foot-square sheet-iron frame slotted parallel to one edge and supplied with a trough. The frame was sunk into the soil, with the slot parallel to and at the soil surface. A 1-foot-square pan perforated with 100 pinholes was set over the top of the frame, and through this water was poured. As the water dropped onto the soil, part of it was absorbed and the remainder ran off, passed through the slot and down the trough, and was caught in a cylinder placed in a soil pit alongside the absorption frame. Water was sprinkled by this method onto 4-~~foot~~ squares in each woods plot and in each field plot at the rate of 1 liter each 5 minutes (5 inches per hour). When the rates of run-off remained the same for two consecutive applications, infiltration was considered constant and recorded as such. Averages were taken of each group of four tests made on woods and field plots.

The relative infiltration rates are presented in table 5 and figure 2. It may be seen that the black locust woods soil differed little in this respect from the corresponding field soil; the differences are not statistically significant. The rate of infiltration under sassafras, however, increased with age of stand, while that on the corresponding field plots remained essentially the same. Here the differences are statistically significant.

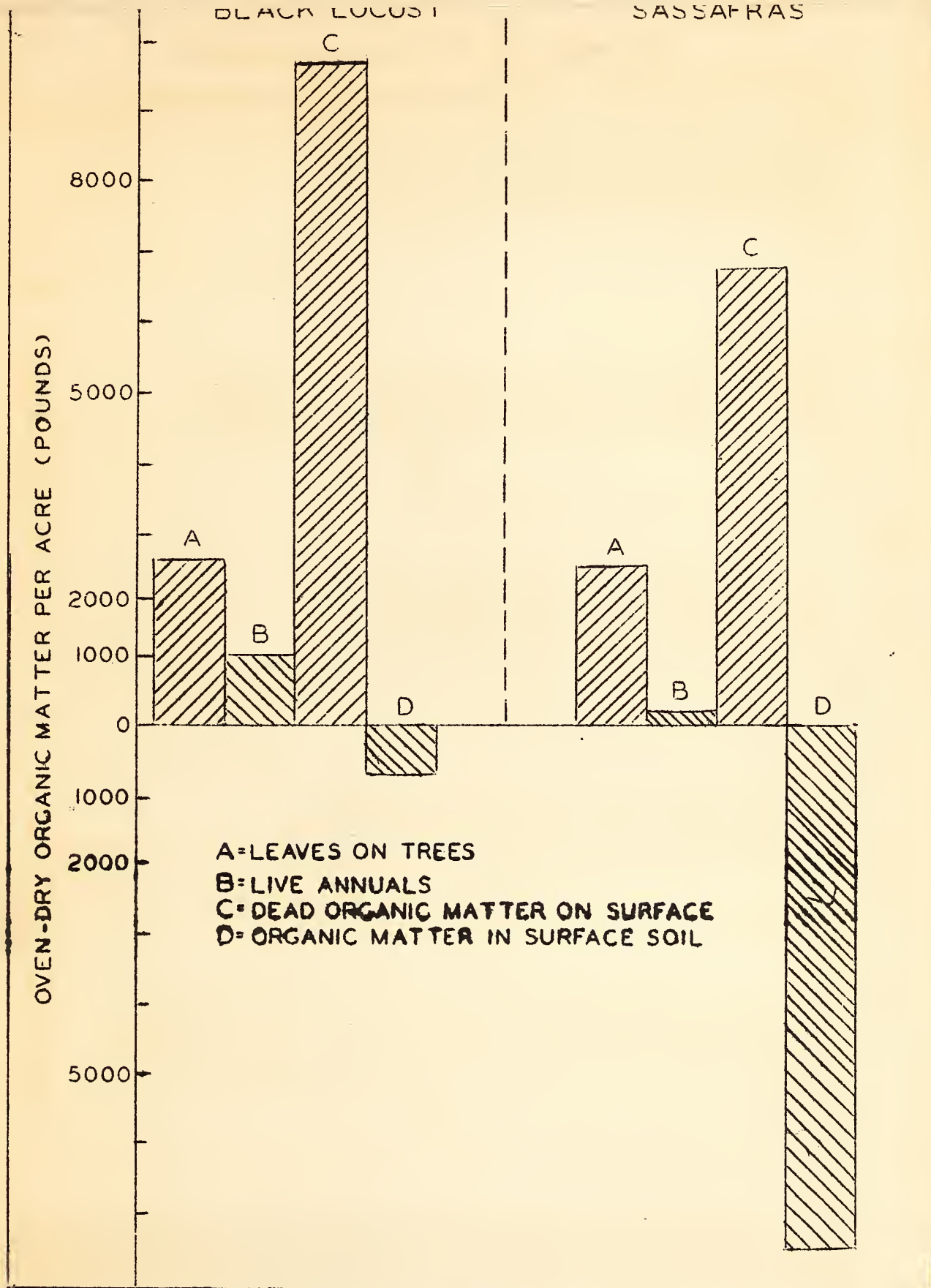


Figure 1.--Quantity and distribution of organic matter produced by trees and lesser vegetation on old-field areas forested with black locust and sassafras, respectively.

BLACK LOCUST

SASSAFRAS

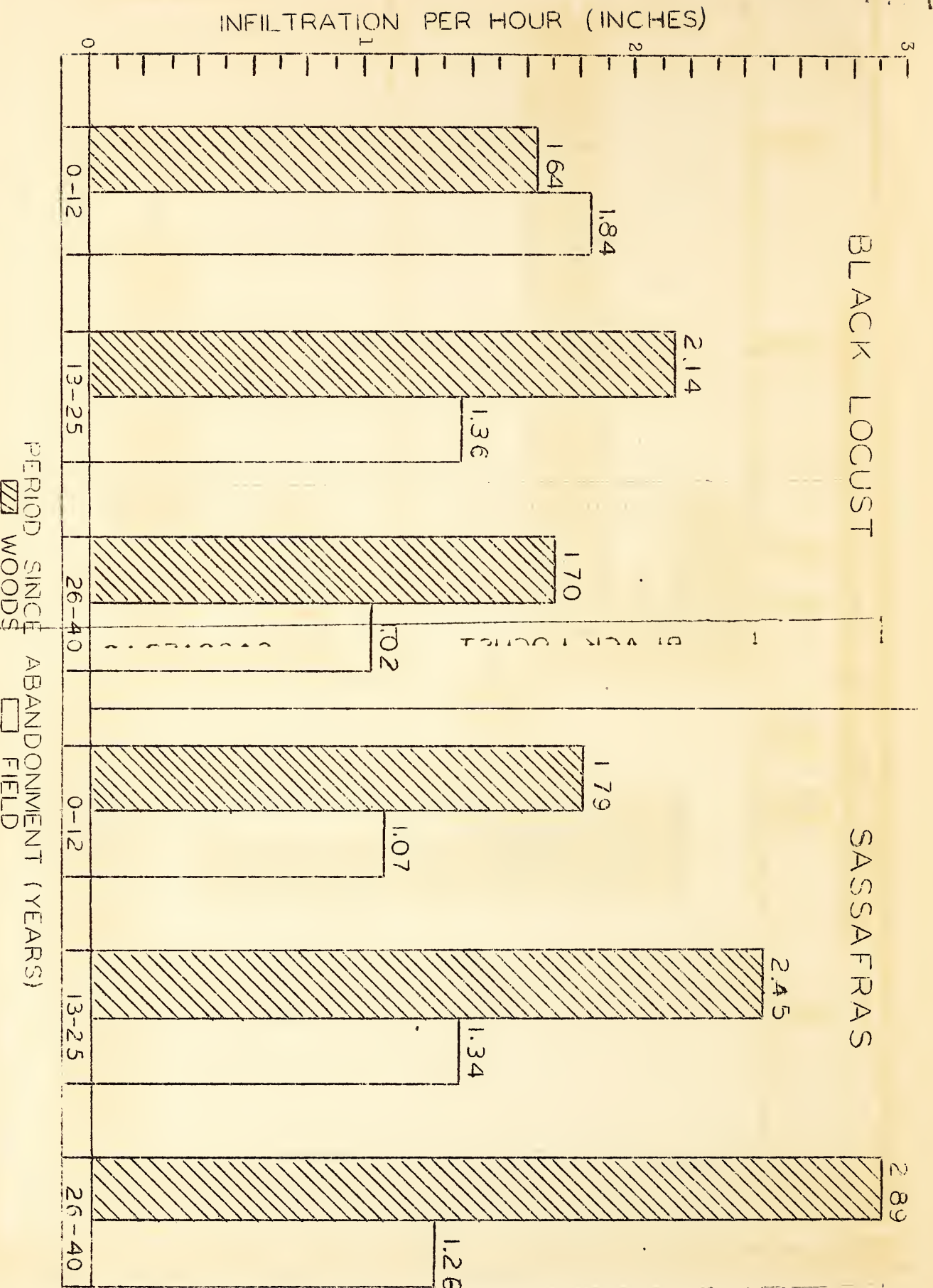


Figure 2.-- Infiltration rates of soils in old fields and under old-field stands of black locust and sassafras.

Table 5.--Infiltration rate per hour under black locust
and sassafras and on matched old-field plots,^{1/}
when rate of application was 5.08 inches per hour

Age (years)	Black locust		Sassafras	
	Woods	Field	Woods	Field
	Inches	Inches	Inches	Inches
0-10	1.64 \pm 0.41	1.84 \pm 0.17	1.79 \pm 0.20	1.07 \pm 0.18
11-20	2.14 \pm 0.24	1.36 \pm 0.19	2.45 \pm 0.24	1.34 \pm 0.20
21-40	1.70 \pm 0.23	1.02 \pm 0.13	2.89 \pm 0.27	1.26 \pm 0.19
All	1.83 \pm 0.13	1.41 \pm 0.10	2.38 \pm 0.14	1.22 \pm 0.10

^{1/} Each figure with its standard error is a mean of 24 determinations for black locust and matched field plots and of 36 determinations for sassafras and matched field plots.

This test was restricted to black locust and sassafras because the effectiveness of pines in increasing infiltration rates in old-field soils had been fully established in earlier investigations.^{2/}

Summary

Black locust, pines (shortleaf, Scots, Austrian, eastern white, and red), and sassafras have been considered as pioneer crops on bare land for forest soil building in the Central States.

Pines were found to rank first in abundance of litter produced, black locust next, and sassafras last. Sassafras litter had become incorporated in the mineral soil to a greater degree than either black locust or pine litter.

Although not a legume, sassafras had caused as great accumulation of total nitrogen in the upper mineral soil as black locust.

Black locust plantings are likely to cause grass to develop on the forest floor, unless they are underplanted with other tree species.

Sassafras proved superior to black locust in causing an increase in infiltration rates of rainfall.

^{2/} Auten, John T. Porosity and Water Absorption of Forest Soils. Jour. Agr. Research 46: 997 - 1014. 1933.

^{1/} The Effect of Forest Burning and Pasturing in the Ozarks on the Water Absorption of Forest Soils. Central States Forest Expt. Sta. Tech. Note 16. 1934.

